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An analogy between the development of the plates of crinoids and the leaves of *Sassafras*

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It is a fact, well known to paleontologists, that the calcareous plates in the arms of crinoids are arranged in a single row in certain species, as in the Pisocrinidae and other members of the order Larviformia, or in a double row, as in *Encrinurus liliiformis* and others. The biserial forms are uniserial at the lower end and here the plates are quadrangular in shape. These latter grade into wedge-shaped plates, which are next followed by biserially arranged and more or less pentagonal-shaped ones.

It was pointed out not long ago, by Dr. A. W. Grabau,* that in a number of forms, in following on toward the tips, the same series of changes is repeated, but in reversed order, so that the uniserial quadrangular plates are again found at the upper ends. There is then, starting from the base and working upward, or from the tip and proceeding downward, a change in the plates from a uniserial to a biserial arrangement and from a quadrangular, more or less regular outline, to one that is irregularly pentagonal. In other words the plates of simplest form and arrangement are at the two extremities and the more complex ones are between them. FIGURES 1a and 1b are reproductions of two of Dr. Grabau's figures illustrating these features.

From the arm plates of crinoids to the leaves of *Sassafras* may seem like a far call, but it is an interesting fact that in the leaf arrangement in many of the branchlets of a season's growth, in suckers, and in seedlings of *Sassafras*, the arrangement of the plates in the biserial crinoid arm is at once suggested. Examination of a large number of specimens collected in Bronx Park has shown none but entire leaves at the bases of all of them, while above these are either or both the bilobed and trilobed ones. The order in which these latter two forms appear is not constant, however. Sometimes the bilobed ones are below the trilobed and vice

* Amer. Jour. Sci. 16 : 289-300. f. 1-11. 1903.

versa. Above these there are again entire leaves. It is not to be understood, however, that this arrangement holds good in all specimens, for while it seems to be a fact that all of them have entire leaves below, with lobed ones following, it is not invariably the

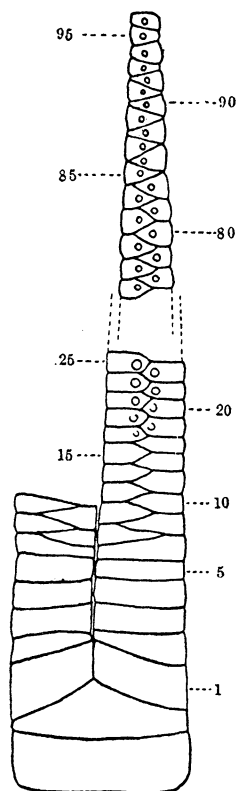


FIG. 1a. *Encrinurus lilliformis*. Diagram of arms, showing arrangement and shape of plates. Reproduction of Grabau's fig. 1a.

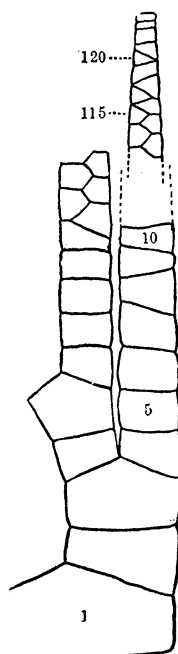


FIG. 1b. *Flatycrinus hemisphericus*. Diagram of part of arm group, showing similar conditions. Reproduction of Grabau's fig. 7.

The numbers on the figures represent the serial numbering of the plates, counted from the basal one upward.

case that there are nothing but entire leaves above. A number of specimens were found in which there were no entire leaves at the top, and others on which the entire and lobed ones were mixed. Examples of two branchlets with the leaf forms and arrangement above described are shown in FIGURES 2a and 2b.

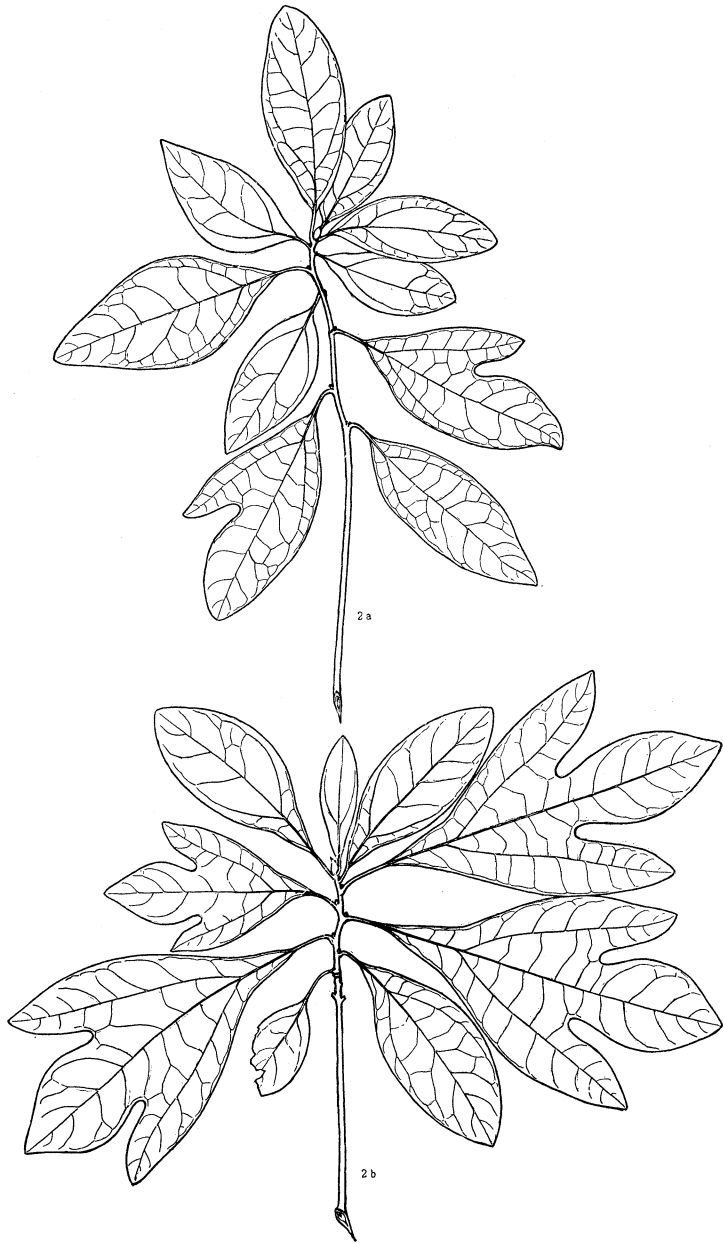
The opening bud in early spring forecasts the subsequent arrangement of the leaves on the stems. The outer ones are entire, while the inner ones are lobed. The upper zone of leaves cannot, however, be seen, as the buds are not yet sufficiently opened, but as the bud expands and the new branch grows the entire leaves remain at intervals along the lower part of the branch, while the lobed ones are carried higher up, and finally the second series of entire leaves unfolds at the top. As, therefore, in the crinoid arm, the simplest forms of structure are found at the base and tip, with the more complex ones between them.

It seems probable that this arrangement of the leaves in *Sassafras* has, like the arrangement of the plates in the biserial crinoid arm, some phylogenetic significance. In regard to the crinoids it is believed that the grouping of the plates epitomizes the life-history or development of the organisms to which they belong, and that this history, having its climax in the central part of the arm, may be read either upward from the base or downward from the tip. It is inferred, therefore, that the earliest crinoids of any genetic series had simple uniserial arms with quadrangular plates, and that gradually the plates became biserial in arrangement and more complex in form. There are also other facts which indicate that this is the correct interpretation.

In like manner the leaf arrangement described seems to indicate that it also summarizes the development of the *Sassafras* branch and its leaves, and that this story may be similarly read, either upward or downward, although the change from entire to lobed leaves is more abrupt and less gradual than is the transition from quadrangular to pentagonal plates in the crinoid arm. If this analogy holds true, it leads to the inference, therefore, that the ancestral type of *Sassafras* had entire leaves and that these are the primitive leaf forms, while the lobed ones are a later development.

Since writing the above my attention has been called to R. T. Jackson's observations on *Sassafras*, in his "Localized Stages in Development in Plants and Animals."* The inference above expressed, however, in regard to the ancestral type of *Sassafras* leaf,

* Mem. Boston Soc. Nat. Hist. 5: 89-153. pl. 16-25. 1899.



FIGS. 2a, 2b. Branchlets of *Sassafras Sassafras* (L.) Karst., showing arrangement of entire and lobed leaves. Collected in Bronx Park, New York, N. Y., October, 1908.

is different from his, which is that the lobed forms are the primitive or ancestral type, and is, I think, more in accord with the recapitulation theory. Indeed, Jackson recognizes the difficulties of his interpretation and that under it *Sassafras* becomes an exception to the usual condition. He says: * "The fact that seedlings start with entire leaves and later acquire lobed leaves like the earliest fossil representatives seems difficult to harmonize with the usual condition, where the first leaves are like the primitive or ancient types, and later leaves are different, being more specialized, as in *Liriodendron*, white ash, and *Platanus*." Now while it is true that what are generally recognized as the earliest ancestral forms of *Sassafras* leaves are lobed, and that apparently there are no entire fossil *Sassafras* leaves known, as remarked by E. W. Berry in his "Notes on *Sassafras*," † nevertheless, as the latter author well says, there are several fossil leaves with entire margins, which are referred to other genera, that might with equal propriety be referred to *Sassafras*, such for example as *Cinnamomum Heerii* Lesq., ‡ and anyone familiar with figures of fossil leaves may readily recall other species in this and other genera which compare very closely with certain of the entire leaf forms in the living *Sassafras*. It may also be pertinent to remark that the determination of genera in fossil botany, based upon leaves only, has not attained to such precision that all leaves can with certainty be referred to their correct genera. Further than this, it may be recalled that even the correctness of the reference of many fossil lobed leaves to the genus *Sassafras* has been questioned or criticized by competent authorities. Thus the fact that lobed leaves were actually the earliest ancestral forms is by no means definitely established. The entire forms may yet be found, either as new discoveries or as species incorrectly referred to other genera. Jackson's interpretation, therefore, which places the lobed leaves as the earliest forms, may not be in accordance with the actual facts, but opposed to them, and since it necessitates an apparent exception to the usual condition, requiring a devious explanation, the better course would seem to be to regard the

* *Loc. cit.* 108.

† *Bot. Gaz.* 34: 426-450. *pl.* 18 + *f.* 1-4. 1902.

‡ *Loc. cit.* 433.

entire leaf as the earliest ancestral form, the fossil representatives of which are at present either undiscovered or perhaps incorrectly referred to certain other lauraceous genera.

Finally, it appears logical to infer in regard to reversionary leaf forms, which are really not reversions but forms which have not developed beyond the ancestral condition, that if they do occur they should appear when the growth of the tree is least vigorous, and that the leaves of full development should appear when the tree is in its period of maximum growth. Growth is least vigorous in early spring, when the tree is awakening from its dormant condition, and in autumn when it is preparing for it. The leaves which appear at these periods are the simplest in form. Summer is the time of maximum vigor of growth and the leaves which appear at that period are the most highly specialized or differentiated. Further than this, in any given growing season the bud for the next season is already being formed. The outer leaves of the bud, which become the lower leaves of the next season's branch, are the first formed and are therefore formed during the early part of the growing season, while the innermost ones, which subsequently become the uppermost ones of the future branch, are formed late in the growing season. These are the simplest in form. The intermediate zone of bud leaves, which are destined to occupy the median part of the branch, are formed during the height of the growing season, when conditions are most favorable for full development. These are the lobed ones.

From every point of view in which actual facts are in our possession it therefore seems reasonable to regard the entire leaves as the type of the ancestral form, and the arrangement of the several leaf forms on the branch as representing the development of the organism as a whole from infancy to maturity and back again to second childhood or old age.

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